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# Relationship between motor reaction time and ability to play football

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- T I T L E -

# RELATIONSHIP BETWEEN MOTOR REACTION TIME AND ABILITY TO PLAY FOOTBALL

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## HISTORY OF PROBLEM

Speed of motor reaction is believed to be a vital factor in football. Many coaches estimate a player's ability largely upon his speed or quick action. Experiments have been performed with the college athlete to determine the relation between reaction time and his ability to perform as an athlete. The author sent letters to several leading colleges of the country concerning experiments conducted with college and high school athletes. These letters were sent to Glen S. Warner, Temple University, Philadelphia, Pennsylvania; W. R. Miles, Yale University, New Haven, Connecticutt; Albert Walton of the Department of Experimental Psychology, Stanford University, Palo Alto, California; and Mr. Griffith of the University of Illinois, Urbana, Illinois.

Answers were received from these universities stating that their work had been in connection with the reaction time of college athletes only. Thus, the author concluded that very probably no extensive work on reaction time in relation to ability to play football had been done with reference to the high school boy.

W. R. Miles and B. C. Graves of the Psychology Laboratories at Stanford University (W. R. Miles is now located at Yale University) have been interested in the reaction time of college football men. They have discovered that there is a very close relation between the players' football "charging ability" and their value as football players. W. R. Miles states, (1) "We therefore conclude that the football charge when it occurs as a response to a signal, the exact timing of which cannot be guessed by the players, requires about 0.4 seconds as an average." He also says, (2) "It appears certain that the coaches who make these rankings were firm in the conviction that speed is a fundamental condition for efficiency in football players." And Professor Miles goes on to say, (3) "They point to the conclusion that speed is important but that first of all it is wise to discover who has the speed and in what degree."

Letters were also sent to the following coaches: Coach B. W. Bierman, University of Minnesota; Coach Lynn Waldorf and Coach Burt Ingwerson, both of Northwestern University; Coach Francis Schmidt, Ohio State University; Coach A. N. McMillin, Indiana University; Coach Harry Kipke, University of Michigan; Coach Andrew Kerr, Colgate

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(1) The Research Quarterly, Oct. 1931, Vol. II, No. 3.

(2) Ibid.

(3) Ibid.

University; Coach E. E. Wieman and Coach H. O. Crisler, both of Princeton University; Coach Lou Little, Columbia University; and Coach Glenn S. Warner, Temple University.

In the letters sent the foregoing coaches a written statement was requested answering the following question: "Is speed based upon reaction time a vital factor in football?"

Answers were received from Coaches A. N. McMillin, B. W. Bierman, Francis Schmidt, Lynn Waldorf and Andrew Kerr.

#1 Coach A. N. McMillin writes the following statement: "In my opinion, speed, based upon reaction time, is one of the most important factors in the development of football players who are to become finished performers. We have no valid or reliable test to measure this speed but are forced to use subjective judgment in doing this phase of the work. -- There is a great deal to be done in this field."

#2 Coach B. W. Bierman writes, "Speed and fast reaction time naturally are two of the most vital factors in football. So many things in football might be classed as 'emergencies' and reaction time largely determines whether this 'emergency' can be properly met."

#3 Coach Francis Schmidt writes as follows: "Speed is probably the most valuable single asset a player can have, especially a back."

#4 Coach Lynn Waldorf writes, "Speed is perhaps the most important single element in the game of football. - - - A team which has a high degree of team speed, by which we generally mean that its members start fast and get to the point of attack quickly, rather than track speed like a one hundred yard sprinter, will usually be far more successful in its game than a slow team. By speed in this connection is meant ability of a back, for instance, to start rapidly in any direction the instant the ball is snapped and the ability of a lineman to react quickly and get across the neutral zone before his opponent. Speed, of course, in this sense is intimately connected with coordination."

#5 Coach Andrew Kerr writes, "There is no question in my mind that speed is very essential in football. In fact I think it is one of the most important features connected with the modern game."

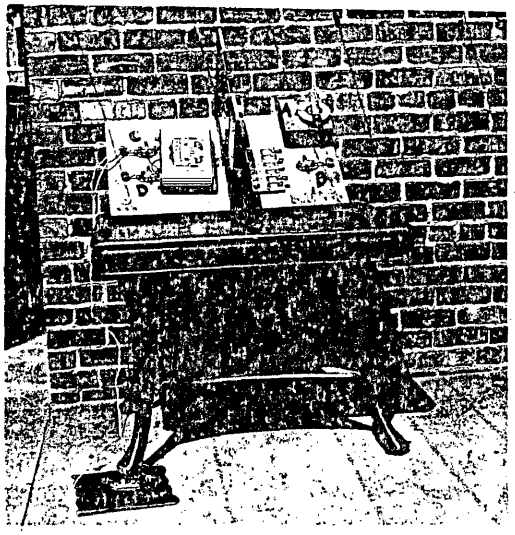
#6 The author inquired from colleges and Psychology Departments if any reaction time tests had been performed on high school football men and received the information that there had not. The author then asked the leading coaches of the country to express their opinion in writing as to the value of speed in football. These written statements were for the purpose of showing that speed was a vital factor in football.

## PROBLEM

Because of universal interest in this field and because many varying opinions are indicated, the problem is to find out, by some systematic inquiry, as to the nature of the relationship between motor reaction time and ability to play football at the high school level.

## MATERIALS AND METHODS

The Marietta Reaction Time Set Machine was used for this experiment. The illustration shows the machine and setup used. The instrument at the upper right hand corner (marked "A") is the Marietta chronoscope or timing machine. This instrument is so regulated as to register hundredths of a second. It is connected by a set of wires with three telegraph keys seen on the board. The key on the right side (marked "B") is operated by the experimenter, and the keys (marked "C" and "D") on the left side are operated by the subject. The two wires from key "C" are connected to the push button on the board on the ground. When this push button is pressed (by stepping upon it), it operates the



Ill. No. 1

same as if the key on the big board had been pushed. This was arranged thus in order to register the subject's foot reaction time.

To perform the test, the experimenter, after instructing the subject, starts the chronoscope and then suddenly presscs key "A" in front of him. This causes a sharp buzzing sound and also causes one of the plates on the timer to rise. The subject on hearing the buzzing sound either presses key "D" on the big board or steps upon the push button on the ground, depending upon which experiment is being performed. This causes the second plate on the timer to rise. After the subject presses his key, the chronoscope is stopped by the experimenter. The reaction time as indicated by the two plates can then be read. This time is always in hundredths of a second.

Subjects were football men from eight high schools who had played during the 1932 season and who had made their letters. The schools selected were as follows: Technical High School, Central High School, North High School, South High School and Benson High School, all of Omaha, Nebraska; Abraham Lincoln High School and Thomas Jefferson High School of Council Bluffs, Iowa; and the High School at Grand Island, Nebraska. The tests were made in December, 1932 and January, 1933, following the 1932 football season.

Two tests for reaction time were taken - one based upon the hand action called Test No. 1 or "Hand Reaction",

and the other based upon foot action called Test No. 2 or "Foot Reaction".

To perform these tests the machine was set up in a school room on a table high enough to prevent the subject seeing the experimenter's hand. Four or five boys were allowed in the room at one time and instructions were given them. The experimenter explained that the machine was a reaction machine capable of telling how fast they could respond to a given signal. They were told that there would be two tests, one for the hand and one for the foot. The one making the test with the aid of his assistant demonstrated what was required and how they were to stand and to what to react.

## TEST NO. 1 - HAND REACTION

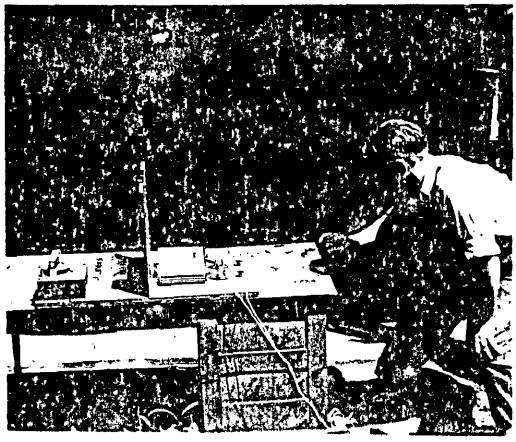
After the demonstration one of the subjects was selected and told that the first test would be the hand reaction test. He was allowed to examine the machine and push the keys until he was thoroughly familiar with it. While he was examining the machine, the others watched him and were at liberty to touch the keys if they so desired.

After allowing this examination, the subject was required to take a crouching position (as shown in illustration No. 2 on the following page) with his hand even with the edge of the table. When the signal was given, the subject quickly pressed key "D". This procedure constituted

one trial.

Practice periods were allowed each subject without a signal from experimenter until his confidence had been gained. Following this were three practice trials with the signal.

Then ten tests were given each subject and the time tabulated upon a data sheet.



Ill. No. 2

## TEST NO. 2 - FOOT REACTION

Following the hand reaction tests, the subject was required to take the position shown in illustration No. 3 on page 10 with feet directly in front of push button. Before this experiment the assistant again demonstrated exactly how to perform the test, and the subject was allowed to orient himself as to the foot action. When the signal was given, the subject quickly pressed the button with his foot. The same practice procedure as in Test No. 1 was allowed.

Ten trials were given each subject and the time again tabulated.

Ill. No. 3

Thus each data sheet contained ten hand reaction times and ten foot reaction times.

The distance between the hand and key on top of the table, and the distance between the push button on the floor and the foot was approximately twelve inches. It is estimated that twelve inches is about the distance the hand or foot travels before contact is made with an opponent in actual football play.

The positions in illustrations numbers 2 and 3 were taken because it was assumed that the subject could react as fast in that position as in any other. It was also assumed that if a player was fast in this position, he would also be fast in the regular football stance.

Using the Pearson Correlation Coefficient Formula, the correlations between the hand and foot reaction times

were calculated in the following manner:

The ten hand tests were added and the average taken, and the same procedure was followed with the foot tests. Thus each subject was given his average hand reaction time and his average foot reaction time. These averages were then correlated. The averages were used throughout the experiment because it was believed that this system gives a more accurate and fair estimate of each subject's reaction.

## RATINGS

The second part of the experiment was based upon personal opinions or ratings. Rating of each subject or player was made in three different ways as follows:

First, each subject was rated by his coach as to his ability in four different phases of the game.

Second, each coach after rating his own men, was asked to give his rating as to the players of the other schools.

Third, sport writers of the Omaha World Herald and the Omaha Bee-News, newspapers in Omaha, Nebraska, passed judgment upon the Omaha players. The sport writer of the Nonpariel of Council Bluffs, Iowa, ranked the Council Bluffs players, while the sport writer of the Grand Island Daily Independent passed judgment upon the Grand Island players. These ratings were made using the five point scale.

Coaches of the different schools were selected to rate the subjects because it was assumed that they would have the best opportunity to thoroughly observe the players. It is a coach's task to understand and teach football. Also besides having close contact with their own players, they necessarily should study and know the caliber of their opponents.

Sport writers were chosen because it is their everyday duty to observe team games, make comments about players and write up the games play by play for their papers. It is also their duty to aid in selecting at the end of the season all-state and all-city football teams. In order to do so, it is assumed that they made a study of the performance of each football man in their respective districts.

At each school where the experiments were performed the coach and his assistant coach or coaches were given rating sheets with the players of their school listed thereon. Each coach was asked to rate his players to his best knowledge. Each rating sheet was kept confidential in order to eliminate the possibility of any of the coaches being influenced by another's rating.

These rating sheets were so divided that the coach could rate his men in four different phases of the game, as follows: "Offense", "Block", "Defense" and "Charge". Each of these headings was to be rated independently. The system of rating used was based upon letters - each letter

representing a certain degree of ability. The letter "E" was used to represent an excellent rating in that particular phase of the game; the letter "G" represented a good rating; the letter "A" showed an average rating; the letter "P" stood for a poor rating; while the letters "VP" indicated very poor. Following is an example of the rating sheets used:

Ill. No. 4

RATING SHEET

School_____ By_____

E - Excellent P - Poor
G - Good VP - Very Poor
A - Average

| Name | Position | Offense | Block | Defense | Charge |
|---|---|---|---|---|---|
| | | | | | |

It will be observed that in the first column is the name of the player and that in the second column is the position he played during the season. The last four columns are headed "Offense", "Block", "Defense", and "Charge", respectively.

After the coaches had graded their own men, they

were given other rating sheets upon which were listed the players of the other schools. They were requested to rate as many of the other men as possible. In a few cases the coaches were unable to recall a player, which accounts for the variation in the number of ratings for each man. Later rating sheets were given to the sport writers who were asked to rate the players of all the schools in this experiment.

Data from these rating sheets were then tabulated. First the rating sheets were separated according to schools and then compiled on a final rating sheet. Thus, when this information was all compiled there were eight final rating sheets representing eight different high schools and one hundred fifty-one football players.

Ill. No. 5

FINAL RATING SHEET

School_____

| Name | Position | Offense | Block | Defense | Charge |
|---|---|---|---|---|---|
| Doe, John | H.B. | E G A | E G A | G G G | G G G |

With reference to illustration No. 5 on the preceding page, the red letters are the ratings of coaches as to their own men; the black letters represent the ratings by other coaches and sport writers.

Then the author attempted to discover how close the coaches' estimates of their own players agreed with the concensus of opinion. In order to show the relationship. the ratings were weighted after the manner of school grading, as follows:

E - 90%
G - 80%
A - 70%
P - 60%
VP - 50%

Each school's rating sheet was then calculated in the following manner:

The red letters in each of the four different fields or phases were given a value according to the foregoing table. The black letters in each division were also given a value and an average was taken. Thus under each head, "Offense", "Defense", "Block" and "Charge", were listed two estimates of the players' ability, one of the coach and the other the concensus of opinion. These two estimates were then correlated.

The red letters for each boy in each phase were then

added and the average taken. This average graded the boy according to his coach's estimate and was called the "coach's final opinion" to distinguish it from the others.

Next were taken the black letters and the same procedure followed. This average rated the boy according to the concensus of opinion and was known as the "final concensus of opinion".

This procedure gave the players two final ratings based upon their ability to play football, one rating giving the coaches' final opinion of their players and the other giving the final concensi of opinion.

In order to give the boys a rating based upon the results of the Marietta Reaction Time Set Machine, each boy's foot and hand reaction times were taken and the average of the two gave him a "machine rating".

Then the coach's final opinion and the final concensus of opinion were correlated with the machine rating of each boy.

To summarize, the coaches of these high schools and sport writers of the respective cities rated each player in the four following phases: "Block", "Charge", "Offense" and "Defense". This gave each boy two ratings in each phase, his coach's and the combined ratings of the other coaches plus the ratings of the sport writers, known as the concensus of opinion.

Correlations were made between the hand and foot reaction times; between the two ratings based upon each phase of the game; between the "machine rating" of each player and his coach's final rating based upon all of the phases of the game; and between the "machine rating" and the final concensus of opinion again based upon all of the phases of the game.

## ANALYSIS

To analyze the problem the results of all correlations had to be taken into consideration. The first correlations were based upon the rating sheets as explained on page 16.

| | |
|---|---|
| Offensive correlation | .522 |
| Block correlation | .83 |
| Defensive correlation | .58 |
| Charge correlation | .69 |

The above figures indicate that the "Block" and "Charge" correlations are higher than the "Offensive" and "Defensive" correlations. This difference may be due to the fact that coaches seem to be more interested in the blocking and charging ability of a player. Or it may be due to the fact that defense and offense are much more complicated and harder to judge than is a single factor such as blocking or charging. Then, on the other hand, the general playing or team work of a team may tend to blot out the specific ability of a player, that is, a well organized or poorly organized team would bias the coach's judgment of a player.

Checking through the estimates of the coaches and

concensi of opinion, it was found that the coaches of seven of the high schools tended to rate their men higher than did the concensi of opinion, while one coach was inclined to underrate his players.

Following, under the number of each of the eight schools is shown, first, the number of times the coach rated his players higher than the concensi of opinion and, second, the number of times the concensi of opinion topped the rating of the coach:

| Schools | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 |
|---|---|---|---|---|---|---|---|---|
| Coaches | 15 | 20 | 12 | 9 | 15 | 10 | 8 | 3 |
| Concensi | 3 | 2 | 5 | 5 | 1 | 3 | 7 | 5 |

Out of the total group, the concensi of opinion and the coaches agreed only eighteen times.

The foregoing figures give the impression that to some extent the "halo effect" has prejudiced the coach in his judgment of his players.

(1) "Many investigators have noted the tendency for general impressions to spread to specific traits, to which

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(1) P. M. Symonds - Diagnosing Personality and Conduct. p.111

tendency Thorndike has given the name 'halo effect'. It is the belief of the author that coaches in describing the worth of their players are prone to raise their valuation of those players who possess fair ability to closely equal that of their good players." Wells states, (1) "There is a possibility of one rather disturbing constant error in measures of this nature whose extent it is never possible to know accurately. There is noted introspectively a tendency to grade for general merit at the same time as for the qualities, and to allow an individual's general position to influence his position in the qualities."

The correlation between the hand reaction time and the foot reaction time was found to be .63. Although this correlation was not as high as was expected, it did show that there was a fairly close relation between the speed of the hand and the speed of the foot.

The hand reaction time for the 151 boys ranged from .30 to .45 of a second with an average of .368 per second. Table No. 1 shows the range. (Table No. 1 will be found on the following page.)

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(1) F.L. Wells - Statistical Study of Literary Merit. Archives of Psychology, No.7 (1907). p. 21.

Table No. 1

| Reaction Time | | No. of Boys |
|---|---|---|
| .30 | | 3 |
| .31 | | 4 |
| .32 | | 9 |
| .33 | | 7 |
| .34 | | 13 |
| .35 | | 23 |
| .36 | (Average) | 16 |
| .37 | | 16 |
| .38 | | 20 |
| .39 | | 11 |
| .40 | | 9 |
| .41 | | 4 |
| .42 | | 8 |
| .43 | | 3 |
| .44 | | 2 |
| .45 | | 3 |

Column one is the reaction time in hundredths of a second. The second column gives the number of boys with the reaction time in column one. Sixteen boys had the average hand reaction time; fifty-nine had faster than average; and seventy-six had slower than average.

The foot reaction time ranged from .35 to .57 of a second with an average of .425 of a second. Table No. 2 on the following page shows their range.

Table No. 2

| Reaction Time | | No. of Boys |
|---|---|---|
| .35 | | 1 |
| .36 | | 1 |
| .37 | | 4 |
| .38 | | 12 |
| .39 | | 11 |
| .40 | | 15 |
| .41 | | 23 |
| .42 | (Average) | 18 |
| .43 | | 13 |
| .44 | | 14 |
| .45 | | 11 |
| .46 | | 10 |
| .47 | | 3 |
| .48 | | 3 |
| .49 | | 4 |
| .50 | | 5 |
| .51 | | 1 |
| .52 | | 0 |
| .53 | | 1 |
| .54 | | 0 |
| .55 | | 0 |
| .56 | | 0 |
| .57 | | 1 |

Eighteen boys had the average reaction time; sixty-seven boys had faster than average; and sixty-six boys had slower than average.

Thus, the two tables show that fifty-nine of the boys had faster than average hand reaction time, and sixty-seven had faster than average foot reaction time.

The two averages, .368 and .425, give a "machine rating" average of .398 of a second.

The following Table clarifies the rating each player received from his coach and the coaches of the other schools.

The schools are listed from "1" to "8", and the players are numbered from "1" to "151".

Reaction time is based upon the machine rating of each player.

The last columns contain the coaches' ratings, each coach being designated by a number from "1" to "13".

The coach of each school is indicated by his number corresponding to the number of that school.

| Schools | Players | Reaction Time | Coaches | |
|---|---|---|---|---|
| | | | #1 | #9 |
| #1 | 1 | 42 | A | G |
| | 2 | 43 | G | G |
| | 3 | 36 | G | G |
| | 4 | 43 | A | G |
| | 5 | 42 | G | A |
| | 6 | 44 | A | G |
| | 7 | 38 | G | E |
| | 8 | 41 | A | P |
| | 9 | 37 | A | G |
| | 10 | 40 | G | A |
| | 11 | 39 | G | E |
| | 12 | 39 | G | G |
| | 13 | 42 | A | A |
| | 14 | 37 | G | G |
| | 15 | 43 | A | P |
| | 16 | 40 | A | A |
| | 17 | 35 | G | P |
| | 18 | 41 | A | A |
| | 19 | 43 | A | P |
| | 20 | 42 | F | A |
| | 21 | 42 | A | A |
| | 22 | 44 | F | V.P |
| | 23 | 39 | G | G |
| | 24 | 42 | A | A |
| | 25 | 44 | F | V.P |
| | 26 | 42 | A | A |
| | 27 | 41 | G | G |
| | 28 | 42 | A | A |
| | 29 | 40 | G | A |

| Schools | Players | Reaction Time | Coaches | | |
|---|---|---|---|---|---|
| | | | #2 | #5 | #10 |
| #2 | 30 | 37 | G | A | A |
| | 31 | 41 | E | A | G |
| | 32 | 40 | F | | |
| | 33 | 39 | G | G | A |
| | 34 | 41 | A | G | G |
| | 35 | 41 | G | | A |
| | 36 | 45 | F | A | A |
| | 37 | 37 | A | | A |
| | 38 | 39 | G | G | |
| | 39 | 35 | G | | A |
| | 40 | 39 | G | A | A |
| | 41 | 38 | E | G | A |
| | 42 | 37 | A | | |
| | 43 | 42 | A | A | A |
| | 44 | 41 | A | A | G |
| | 45 | 38 | A | G | G |
| | 46 | 40 | E | | A |
| | 47 | 35 | E | A | G |
| | 48 | 43 | G | | |

| Schools | Players | Reaction Time | Coaches | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | #3 | #12 | #13 | #8 | #7 | # 2 |
| #3 | #49 | 43 | A | A | A | G | E | A |
| | 50 | 40 | A | | G | G | G | G |
| | 51 | 38 | F | | F | | E | |
| | 52 | 43 | A | | A | | A | |
| | 53 | 38 | G | A | A | | | |
| | 54 | 40 | A | | A | A | G | |
| | 55 | 37 | G | | G | | | G |
| | 56 | 43 | G | | E | | G | A |
| | 57 | 36 | A | | A | G | | G |
| | 58 | 38 | G | | G | | | |
| | 59 | 45 | A | E | G | G | G | G |
| | 60 | 49 | A | G | G | | A | |
| | 61 | 45 | A | | G | G | | A |

| | | | #4 | #6 | #11 |
|---|---|---|---|---|---|
| #4 | 62 | 36 | G | G | G |
| | 63 | 40 | A | A | A |
| | 64 | 45 | G | E | A |
| | 65 | 45 | A | A | P |
| | 66 | 33 | A | A | G |
| | 67 | 37 | G | E | A |
| | 68 | 49 | G | A | G |
| | 69 | 46 | A | E | G |
| | 70 | 37 | G | G | G |
| | 71 | 48 | G | E | G |
| | 72 | 38 | G | E | G |
| | 73 | 43 | G | E | G |
| | 74 | 46 | A | A | A |
| | 75 | 34 | G | G | G |
| | 76 | 43 | A | E | G |
| | 77 | 40 | F | P | A |

| | | | #5 | #2 |
|---|---|---|---|---|
| #5 | 78 | 47 | A | G |
| | 79 | 35 | A | P |
| | 80 | 40 | G | |
| | 81 | 40 | A | G |
| | 82 | 40 | A | |
| | 83 | 39 | F | A |
| | 84 | 39 | A | |
| | 85 | 36 | A | G |
| | 86 | 42 | A | A |
| | 87 | 37 | G | |
| | 88 | 40 | A | A |
| | 89 | 44 | A | |

| Schools | Players | Reaction Time | Coaches | | |
|---|---|---|---|---|---|
| | | | #6 | #11 | #4 |
| | #90 | 50 | G | G | G |
| | 91 | 41 | E | G | G |
| | 92 | 53 | A | A | |
| | 93 | 39 | F | A | A |
| | 94 | 39 | E | G | A |
| | 95 | 38 | A | G | A |
| | 96 | 39 | F | G | A |
| | 97 | 34 | E | G | E |
| | 98 | 38 | E | G | E |
| | 99 | 39 | F | A | |
| | 100 | 39 | F | G | |
| #6 | 101 | 42 | E | G | |
| | 102 | 38 | E | G | G |
| | 103 | 37 | E | G | |
| | 104 | 36 | E | A | A |
| | 105 | 33 | E | A | G |
| | 106 | 38 | E | G | E |
| | 107 | 38 | E | G | A |
| | 108 | 43 | E | G | |
| | 109 | 39 | F | A | A |
| | 110 | 39 | F | G | G |
| | 111 | 39 | G | A | |
| | 112 | 36 | G | A | A |

| | | | #7 | #12 | #13 | #3 | #10 | #2 |
|---|---|---|---|---|---|---|---|---|
| | 113 | 44 | A | A | | | | |
| | 114 | 41 | E | E | A | E | A | G |
| | 115 | 38 | A | A | | | | |
| | 116 | 41 | A | A | G | F | | A |
| | 117 | 40 | G | G | | | A | A |
| | 118 | 38 | A | A | G | F | A | |
| | 119 | 32 | G | G | | | | |
| #7 | 120 | 43 | F | F | A | | A | G |
| | 121 | 43 | G | G | | A | | |
| | 122 | 37 | A | A | | | | |
| | 123 | 41 | A | A | G | F | F | A |
| | 124 | 45 | G | G | | | | |
| | 125 | 37 | F | F | A | F | | F |
| | 126 | 44 | F | F | | | | A |
| | 127 | 40 | G | G | G | F | A | |
| | 128 | 39 | A | G | G | F | F | A |

| Schools | Players | Reaction Time | Coaches | | | |
|---|---|---|---|---|---|---|
| | | | #8 | #10 | #13 | #3 |
| #8 | #129 | 38 | A | A | G | A |
| | 130 | 43 | A | A | G | A |
| | 131 | 40 | A | A | | G |
| | 132 | 39 | F | A | F | |
| | 133 | 37 | G | A | E | G |
| | 134 | 35 | G | A | | F |
| | 135 | 40 | A | G | G | A |
| | 136 | 37 | F | F | F | A |
| | 137 | 42 | F | F | | A |
| | 138 | 42 | A | A | A | G |
| | 139 | 37 | A | A | | G |
| | 140 | 56 | G | A | G | G |
| | 141 | 34 | E | G | F | E |
| | 142 | 38 | A | A | | G |
| | 143 | 41 | G | A | G | A |
| | 144 | 40 | G | A | | F |
| | 145 | 37 | A | A | G | A |
| | 146 | 36 | A | A | | F |
| | 147 | 41 | G | A | G | A |
| | 148 | 38 | G | A | A | F |
| | 149 | 36 | A | A | | G |
| | 150 | 41 | A | A | | G |
| | 151 | 38 | A | F | A | F |

Table No. 3 was tabulated in order to show the comparison between the average reaction time of "machine rating" of each boy and his final rating as a football player by his coach and concensus of opinion.

Table No. 3

| Reaction Time | E.G. | E.A. | G.A. | A.G. | G. | A. | A.P. | P.A. | P. | V.P. * | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| .33 | | | | | | 1 | | | | | Faster than Average Reaction Time |
| .34 | 2 | | | | 1 | | | | | | |
| .35 | 1 | | 3 | | | 1 | | | | | |
| .36 | 1 | | 2 | | 2 | 2 | 2 | | | | |
| .37 | | 1 | 3 | | 3 | 4 | 3 | 1 | 1 | | |
| .38 | 6 | | 2 | 1 | 2 | 7 | 1 | 1 | 1 | | |
| .39 | 1 | | 3 | | 3 | 3 | 3 | | 4 | Average | |
| .40 | 1 | | 5 | 1 | 2 | 7 | | | 2 | | Slower than Average Reaction Time |
| .41 | 3 | | 3 | | 1 | 5 | 2 | | | | |
| .42 | 1 | | | 2 | | 5 | 4 | | 2 | | |
| .43 | 2 | | 2 | | 3 | 3 | 3 | 1 | 1 | | |
| .44 | | | 1 | | | 2 | | | 1 | 1 | |
| .45 | | | 1 | | 1 | 2 | 1 | | 1 | | |
| .46 | | 1 | | | | 1 | | | | | |
| .47 | | | | 1 | | | | | | | |
| .48 | 1 | | | | | | | | | | |
| .49 | | | | | | 2 | | | | | |
| .50 | | | | | 1 | | | | | | |
| TOTAL | 19 | 2 | 25 | 5 | 19 | 45 | 19 | 3 | 13 | 1 | |

* "E" stands for Excellent; "G" for Good; "A" for Average; "P" for Poor; and "VP" for Very Poor.

With reference to the foregoing table No. 3, the first letter stands for the coaches'opinions, and the second indicates the concensi of opinion. Thus, the first column states that the coaches estimated two players with a reaction time of .34 as Excellent players, while the concensi of opinion estimated them as Good players. And then in the second column the coaches rated their players as Excellent, and the concensi of opinion rated them as Average.

It is shown from this table that the fastest individual tested was rated by his coach and the concensus of opinion as an average player. Two individuals with "machine ratings" of .34 were rated by their coaches as Excellent players and by the concensi of opinion as Good players, and one individual was rated by both as a Good player.

Only eleven boys with a "machine rating" of faster than average were rated as "Excellent-Good" or "Excellent-Average" players.

Of the whole group twenty-one boys were listed as "Excellent-Good" or "Excellent-Average" players with a reaction time varying from .34 to .48. And of this group only eleven had faster than average reaction time.

The final correlations were made using, first, the "machine ratings" of each player and the final concensus of opinion, and second, the "machine rating" and the coach's final opinion.

coach's final opinion.

The concensi of opinion and the coaches' opinions were averaged from their four ratings in each phase of the game as explained on page 16.

Machine rating and final concensus of opinion . . . .09

Machine rating and the coaches' final opinions . . .04

The above correlations show that there is nothing in common between speed of reaction time and concensus of opinion or the coaches' opinions.

The hand and foot correlation showed a relation of .63.

The correlations based upon the coach's opinion and concensus of opinion in the four different phases of the game were as follows:

| | | |
|---|---|---|
| Offense | - | .52 |
| Block | - | .83 |
| Defense | - | .58 |
| Charge | - | .69 |

These correlations brought out the fact that it is easier to judge a specific task rather than a combination of tasks such as would be required in offense and defense.

When the machine ratings of each player were

concensi of opinion ratings, the correlations were .04 and .09, respectively.

# S U M M A R Y

Evidence is here presented to show that a fast reaction time does not necessarily indicate a good football player. This opinion is contrary to that held by many leading coaches.

It is difficult to pick a good high school football player by using only the reaction time results.

A reaction time test shows the coach his fastest reacting men, thus making it possible to make use of this knowledge.

Correlations between the concensus of opinion and the individual coach's opinion within each school system bring out the fact that it is easier to pick out a specific playing reaction rather than a complicated one which brings in a combination of reactions.

The following four correlations, designated in this thesis as the "Offense", "Defense", "Charge" and "Block" correlations, were each computed by taking the concensus of opinion in each of the above phases of the game and the individual coach's opinion within each school system.

The offensive correlation, .52, which had the lowest agreement may be so because of the fact that team play has blocked out a particular individual's ability, or it may be because it is more difficult to judge.

The same may be said of the defensive correlation, .58, although it is slightly higher than the offensive correlation.

The charging correlation (a specific ability) with an agreement of .69 tends to prove the statement that specific abilities are easier to detect.

The block correlation (also a specific ability) with an agreement of .83 shows that this particular ability is readily noted by all coaches.

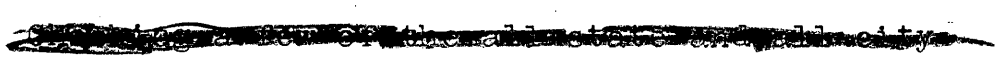
Then, again, the blocking and charging correlations may be higher because the opposing coaches are more interested in the blocking and charging abilities of their opponents.

A fast hand reaction time does not necessarily indicate a fast foot reaction time. A correlation of .63 between the hand and foot reaction times brings out this fact.

## OBSERVATION

One of the best centers tested was recommended very highly by his coach because of his ability to pass accurately and always at the same speed. Because of this ability the backfield men always received the ball at the same point and no fumbles occurred all season. (Only one team was able to make this report). When this player was tested, it was found that his reaction time although fast never varied.

Two teams during the season each had a tackle that was off-side many times during a game. One team claimed they lost the state championship because their tackle was off-side when they scored their last touch down. When asked about this tackle, the coach stated that all through the season this player was continually off-side. Many changes were made but no remedy seemed to be effective. So the team played throughout the season, losing the championship, as the coach stated, "because of this tackle's speed". Both teams were tested and it was found that both centers had a fairly slow reaction time while their fast tackles had a very fast reaction time. When the starting signal was given, it can clearly be seen why these tackles were off-side. They reacted faster than did the centers.



Checking a few of the all-state and all-city football players, it was found that two all-state players, one an end and one a guard, had an exceptionally fast reaction time, while a center that was selected (although many objected to the selection) rated a slow reaction time. According to many coaches the best center was not selected as all-state but as all-city. His reaction time was equal to that of the end and that of the guard, the reaction time of all three being .32 of a second for the hand and .37 of a second for the foot. The center that was selected for all-state had the slow reaction time of .40 of a second for his hand and .45 of a second for his foot. There is a question in the experimenter's mind if the three all-state players selected would have functioned well on the same team because of this reaction variation.

In schools where there was more than one coach, they failed to agree as to the different abilities of a player. One coach rated a player high in one field and low in another, while another coach made ratings just the opposite. The most outstanding individuals were rated by all coaches very nearly alike, but an average player ranged along the scale from "Very Poor" to "Excellent". In some cases there was a difference as to where the players should be played, whether in the line or in the back field. Many times a football player has played three years on the line, and then because of lack of material this same individual has been shifted to the back field for his last year of competition.

also be reversed.

Everything being equal, the author believes a lineman should have the fastest hand reaction, and a back field player should have the fastest foot reaction. If this view is correct, how can a coach by observation only discover in his players their reaction time? He has no way of doing so and must therefore depend on guesswork and hope for the best. Also, the center's reaction time should be under most systems of play now in vogue as fast or faster than that of any player on the line.

Referring to W. R. Liles' work, one of the coaches he interviewed said, "It took me two years to decide on those selections, but apparently you got a line on some of these men in about twenty minutes." Of course it is recognized that the coach's appraisal included many other factors besides that of speed.

# A P P E N D I X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(COPY)

Osceola, Nebraska

April 29, 1936

Coach B. W. Bierman

University of Minnesota

Minneapolis, Minnesota

Dear Sir:

I am taking this privilege to ask you to give me a written statement as to your opinions on the value of speed in football.

I am working on a master's degree in psychology and my thesis is on the reaction time of high school football men. I have inquired into different psychology departments in different schools, but have not found any work in this field. Most of the work has been done with college men.

I must have written statements from the leading coaches to show that speed based upon reaction time is a vital factor.

Your assistance will be greatly appreciated.

Very truly yours,

(Signed) R. E. Snygg

(COPY)

Speed and fast re-action naturally are two of the most vital factors in football. So many things in football might be classed as emergencies, and reaction time largely determines whether this "emergency" can be properly met.

Also football is almost entirely a game of motion -- with most of the assignments working out as follows. The player assumes a stance in one location, and must move elsewhere to carry out his assignment. He may only have to move two feet to strike, or he may have to move 45 yards to cover a kick. In either case his speed is a vital factor.

(Signed) B. W. Bierman

(COPY)

COLGATE UNIVERSITY ATHLETIC COUNCIL

Huntington Gymnasium

Hamilton, N.Y.

May 6, 1936.

Mr. R. E. Snygg,
Osceola, Nebraska.

Dear Mr. Snygg:

There is no question in my mind that speed is very essential in football. In fact I think it is one of the most important features connected with the modern game.

While I admit the necessity of speed yet I regret to state that I have made no experiments on the reaction time of football men that you may use in your thesis. You may quote me, however, as saying that it is my opinion that speed based upon reaction time is a vital factor in modern football.

Sincerely yours,

(Sgd.) Andrew Kerr

Andrew Kerr
Football Coach

AK:J

(COPY)

SPRINGVILLE CANNING CO.

Springville, Erie Co., N. Y.

Speed and quick starting are two of the main requisites of a good football player, quick reaction to starting signals or getting off with the snap of the ball are vital to the success of any team whether on the offense or defense, but especially important in offensive play. I would say that quickness in starting is more important than speed in running because in the average football play the players do not run more than ten or twelve yards and those players who get a fast start will go ten yards much quicker than players who start slowly, although they may be fast runners when under way.

(Signed) Glenn S. Warner.

(COPY)

INDIANA UNIVERSITY

Bloomington, Indiana

Department of
Physical Education for Men
Office of the Director

May 5, 1936

Coach R. E. Snygg
Osceola, Nebraska

Dear Coach Snygg:

In my opinion, speed, based on reaction time, is one of the most important factors in the development of football players who are to become finished performers.

We have no valid or reliable tests to measure this speed but are forced to use subjective judgment in doing this phase of the work.

There is a great deal to be done in this field. Hoping that this statement will help you in your research, I am

Sincerely yours,

(Signed) A.N. "Bo" McMillin

A. N. "Bo" McMillin
Head Football Coach

ANM:BH

C O P Y

Dear Snygg

Speed is probably the most valuable single asset a player can have, especially a back.

Spirit probably ranks with it.

These two qualifications will go a long way toward making a place on your team.

(Signed) Francis Schmidt.

NORTHWESTERN UNIVERSITY

Department of Physical Education and Athletics

Evanston, Ill.

May 5, 1936

Coach R. E. Snygg
Osceola, Nebraska

Dear Mr. Snygg:

I have your letter asking me to give you a statement regarding the value of speed in football. I am not just sure how you are defining the term "reaction time" in your thesis. The paragraph follows:

"Speed is perhaps the most important single element in the game of football. A team which has a high degree of team speed, by which we generally mean that its members start fast and get to the point of attack quickly, rather than track speed like the 100 yard sprinter, will usually be far more successful in its games than the slow team. By speed in this connection is meant ability of a back, for instance, to start rapidly in any direction the instant the ball is snapped and the ability of a lineman to react quickly and get across the neutral zone before his opponent. Speed, of course, in this sense is intimately connected with coordination. We say, for instance that a defensive player is fast when he moves quickly across the line of scrimmage and is able to recover from a block and make the tackle."

I hope the above will meet your requirements.

Sincerely yours,

(Signed) Lynn O. Waldorf

Lynn O. Waldorf
Coach of Football

LOW:RS

FOOT - x

| HAND y | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | | | | | | | | | | | | | 0 | 5 | 0 | | |
| 44 | | | | | | 3 | | | 1 | 1 | | | 5 | 4 | 20 | 80 | 48 |
| 42 | | | | 1 | 1 | 1 | 4 | 1 | 2 | | | 1 | 11 | 3 | 33 | 99 | 78 |
| 40 | | | | | 3 | 5 | 3 | 1 | 1 | | | | 13 | 2 | 26 | 52 | 36 |
| 38 | | | | 9 | 7 | 8 | 4 | 2 | 1 | | | | 31 | 1 | 31 | 31 | 17 |
| 36 | | 1 | 4 | 10 | 8 | 4 | 1 | 3 | 1 | | | | 32 | 0 | (110) | | |
| 34 | | 1 | 11 | 13 | 7 | 3 | 1 | | | | | | 36 | -1 | -36 | 36 | 33 |
| 32 | | 2 | 5 | 3 | 5 | 1 | | | | | | | 16 | -2 | -32 | 64 | 36 |
| 30 | 1 | 1 | 3 | 2 | | | | | | | | | 7 | -3 | -21 | 63 | 45 |
| | | | | | | | | | | | | | (151) | (-89) | (425) | (293) | |
| f | 1 | 5 | 23 | 38 | 31 | 25 | 13 | 7 | 6 | 1 | 0 | 1 | | | | | |
| d | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | |
| fd | -4 | -15 | -46 | -38 | (-103) | 25 | 26 | 21 | 24 | 5 | 0 | 7 | (108) | | | | |
| fd | 16 | 45 | 92 | 38 | 0 | 25 | 52 | 63 | 96 | 25 | 0 | 49 | (501) | | | | |

$\frac{\Sigma XY}{N} = \frac{293}{151} = 1.94$

$C_x C_y = .085$

$C_x = \frac{-103+108}{151} = .033$ $\quad C_y = \frac{-89+110}{151} = .139$

$\sigma_x \sigma_y = 3.04$

$S^2_x = \frac{501}{151} = 3.317$ $\quad S^2_y = \frac{425}{151} = 2.814$

$\sigma_x = 1.82$ $\quad \sigma_y = 1.67$

$r = \frac{\frac{\Sigma XY}{N} - C_x C_y}{\sigma_x \sigma_y} = \frac{1.94 - .085}{3.04} = \frac{1.935}{3.04} = .63$

HAND and FOOT

MACHINE - x

CONCENSUS y

| y \ x | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | f | d | fd | fd xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | | | | | | | | | | | | | | | 0 | 6 | 0 | |
| 87 | | | | | | 1 | | | | 1 | | | | 1 | | | 1 | | 4 | 5 | 20 | 100 15 |
| 84 | | | | | | | | 2 | | 2 | 1 | | 3 | | 1 | | 1 | | 10 | 4 | 40 | 160 32 |
| 81 | 1 | | | | | | | 2 | | | 1 | 3 | 4 | 1 | 1 | | 1 | | 14 | 3 | 42 | 126 24 |
| 78 | | 1 | 1 | | 1 | 2 | | 1 | 3 | 2 | 4 | 3 | 1 | 3 | 2 | 1 | | | 25 | 2 | 50 | 100 -34 |
| 75 | | 1 | | 1 | | 1 | | 2 | 1 | 3 | 1 | 3 | 3 | 1 | 2 | 1 | | 1 | 21 | 1 | 21 | 21 0 |
| 72 | | | | | 1 | | 1 | 2 | | 3 | 4 | 2 | 3 | 3 | 1 | 3 | | | 23 | 0 | (173) | |
| 69 | | | | | | | 3 | 2 | 4 | 2 | 5 | 4 | 6 | 4 | 2 | | | | 32 | -1 | -32 | 32 -8 |
| 66 | | | | | | 2 | | 2 | 4 | 1 | 2 | | 1 | 2 | | | | | 14 | -2 | -28 | 56 34 |
| 63 | | | | | | | | 1 | 1 | | | 2 | 1 | 1 | | | | | 6 | -3 | -18 | 54 -6 |
| 60 | | | | | | | 1 | | | | | | | | | | | | 1 | -4 | -4 | 16 16 |
| 57 | | | | | | | 1 | | | | | | | | | | | | 1 | -5 | -5 | 25 20 |
| f | 1 | 2 | 1 | 1 | 2 | 6 | 6 | 14 | 13 | 14 | 18 | 17 | 22 | 16 | 9 | 5 | 3 | 1 | (151) | | (-87) | 690 93 |
| d | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | |
| fd | -10 | -18 | -8 | -7 | -12 | -30 | -24 | -42 | -26 | -14 | (-191) | 17 | 44 | 48 | 36 | 25 | 18 | 7 | (195) | | | |
| fd | 100 | 162 | 64 | 49 | 72 | 150 | 96 | 126 | 52 | 14 | 0 | 17 | 88 | 144 | 144 | 125 | 108 | 49 | (1560) | | | |

CONCENSUS and MACHINE

COACHES and MACHINE

MACHINE = x

COACHES y

| y | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | 1 | | 1 | | 1 | | | 2 | 1 | 3 | 1 | | 6 | 1 | 1 | 1 | 2 | | 21 | 6 | 126 | 756 | 6 |
| 87 | | | | | | 1 | | 1 | | 1 | | 1 | 1 | 2 | 1 | | | | 8 | 5 | 40 | 200 | 20 |
| 84 | 1 | | | | | | 1 | 3 | | 2 | 2 | 3 | | | 1 | 2 | | | 15 | 4 | 60 | 240 | -32 |
| 81 | | | | | | 1 | | 1 | 1 | 1 | 5 | 3 | 4 | 4 | 2 | 1 | 1 | | 24 | 3 | 72 | 216 | 93 |
| 78 | | | | | | | 1 | | 1 | 1 | 2 | 1 | | 1 | 1 | | | | 8 | 2 | 16 | 32 | 2 |
| 75 | | 2 | | 1 | | | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | 1 | | | | 12 | 1 | 12 | 12 | -28 |
| 72 | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | | 2 | 1 | | | | | 11 | 0 | (326) | | |
| 69 | | | | | 1 | 1 | | 4 | 6 | 2 | 3 | 2 | 6 | 5 | 1 | 1 | | 1 | 33 | -1 | -33 | 33 | -8 |
| 66 | | | | | | 1 | 2 | 1 | 2 | | 1 | 3 | 3 | 2 | | | | | 15 | -2 | -30 | 60 | 10 |
| 63 | | | | | | | | | | | | 2 | | | | | | | 2 | -3 | -6 | 18 | -6 |
| 60 | | | | | | | | | | | 1 | | | | | | | | 1 | -4 | -4 | 16 | 0 |
| 57 | | | | | | | | | | | | | | | | | | | 0 | -5 | 0 | | |
| 54 | | | | | | | 1 | | | | | | | | | | | | 1 | -6 | 6 | 36 | 24 |
| f | 2 | 2 | 1 | 1 | 2 | 5 | 7 | 14 | 13 | 13 | 19 | 16 | 23 | 16 | 8 | 5 | 3 | 1 | (151) | (-79) | (619) | (81) | |
| d | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | |
| fd | -20 | -18 | -8 | -7 | -12 | -25 | -28 | -42 | -26 | -13 | (-199) | 16 | 46 | 48 | 32 | 25 | 18 | 7 | (192) | | | | |
| fd | 200 | 162 | 64 | 49 | 72 | 125 | 112 | 126 | 52 | 13 | 0 | 16 | 92 | 144 | 128 | 125 | 108 | 49 | (1637) | | | | |

# OFFENSE

Coach - x

| | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | | | 1 | | 3 | 4 | 6 | 24 | 144 | 60 |
| 87 | | | | | 3 | | | | 11 | 14 | 5 | 70 | 350 | 150 |
| 84 | | | | | | | 1 | | 4 | 5 | 4 | 20 | 80 | 52 |
| 81 | | | | | 2 | | | | 3 | 5 | 3 | 15 | 45 | 21 |
| 78 | | | | | 7 | | 5 | | 7 | 19 | 2 | 38 | 76 | 38 |
| 75 | 1 | | 2 | | 10 | | 12 | | 6 | 31 | 1 | 31 | 31 | 9 |
| 72 | | | | | 6 | | 5 | | 3 | 14 | 0 | (198) | | |
| 69 | | | 4 | | 23 | | 13 | | 3 | 43 | -1 | -43 | 43 | 13 |
| 66 | | | | | 3 | | | | 1 | 4 | -2 | -8 | 16 | 0 |
| 63 | | | 2 | | 7 | | | | | 9 | -3 | -27 | 81 | 39 |
| 60 | | | 1 | | 1 | | | | | 2 | -4 | -8 | 32 | 16 |
| 57 | | | | | | | | | | 0 | -5 | 0 | | |
| 54 | | | | | 1 | | | | | 1 | -6 | -6 | 36 | 6 |
| f | 1 | 0 | 9 | 0 | 63 | 0 | 37 | 0 | 41 | (151) | | (-92) | (934) | (404) |
| d | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | | | | | |
| fd | -5 | -0 | -27 | -0 | -63 | (-95) | 37 | 0 | 123 | (160) | | | | |
| fd | 25 | 0 | 81 | 0 | 63 | 0 | 37 | 0 | 369 | (575) | | | | |

$\frac{\Sigma XY}{N} = \frac{404}{151} = 2.675$

$C_X C_Y = .3014$

$O_X O_Y = 4.54$

$C_X = \frac{-95+160}{151} = .430$ $\quad C_Y = \frac{188-92}{151} = .701$

$S_X^2 = \frac{575}{151} = 3.807$ $\quad S_Y^2 = \frac{934}{151} = 6.185$

$O_X = 1.903$ $\quad O_Y = 2.386$

$r = \frac{\frac{\Sigma XY}{N} - C_X C_Y}{O_X O_Y} = \frac{2.675 - .3014}{4.54} = \frac{.237}{4.54} = .522$

# D E F E N S E

Coach - x

| | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | 1 | | | | 3 | 4 | 6 | 24 | 144 | 48 |
| 87 | | | | | | | | | 7 | 7 | 5 | 35 | 175 | 105 |
| 84 | | | | | 1 | | 1 | | 4 | 6 | 4 | 24 | 96 | 48 |
| 81 | | | | | 1 | | 1 | | 9 | 11 | 3 | 33 | 99 | 81 |
| 78 | | | | | 6 | | 4 | | 8 | 18 | 2 | 36 | 72 | 44 |
| 75 | | | 3 | | 12 | | 7 | | 9 | 31 | 1 | 31 | 31 | 19 |
| 72 | | | 1 | | 8 | | 4 | | 4 | 17 | 0 | (183) | | |
| 69 | | | 2 | | 20 | | 6 | | 3 | 31 | -1 | -31 | 31 | 11 |
| 66 | | | 1 | | 4 | | | | | 5 | -2 | -10 | 20 | 14 |
| 63 | | | 1 | | 11 | | | | 1 | 13 | -3 | -39 | 117 | 33 |
| 60 | 1 | | | | 4 | | 1 | | | 6 | -4 | -24 | 96 | 32 |
| 57 | | | | | | | | | | 0 | -5 | 0 | | |
| 54 | | | 2 | | | | | | | 2 | -6 | -12 | 72 | 36 |
| | | | | | | | | | | (151) | | (-116) | (953) | (471) |
| f | 1 | 0 | 10 | 0 | 68 | 0 | 24 | 0 | 48 | | | | | |
| d | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | | | | | |
| fd | -5 | -0 | -30 | -0 | -68 | (-103) | 24 | 0 | 144 | (168) | | | | |
| fd | 25 | 0 | 90 | 0 | 68 | | 24 | 0 | 432 | (639) | | | | |

$\frac{\Sigma xy}{N} = \frac{471}{151} = 3.118$

$C_x C_y = .190$

$\sigma_x \sigma_y = 4.975$

$C_x = \frac{-103 + 168}{151} = .430$ $\quad C_y = \frac{-116 + 183}{151} = .443$

$S^2_x = \frac{639}{151} = 4.231$ $\quad S^2_y = \frac{953}{151} = 6.311$

$\sigma_x = 2.011$ $\quad \sigma_y = 2.474$

$r = \frac{\frac{\Sigma xy}{N} - C_x C_y}{\sigma_x \sigma_y} = \frac{3.118 - .190}{4.975} = \frac{2.928}{4.975} = .58$

# B L O C K

Coach - x

| y | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | | | | | | 0 | 6 | 0 | | |
| 87 | | | | | | | 1 | | 3 | 4 | 5 | 20 | 100 | 50 |
| 84 | | | | | | | 2 | | 9 | 11 | 4 | 44 | 176 | 116 |
| 81 | | | | | | | 4 | | 16 | 20 | 3 | 60 | 180 | 156 |
| 78 | | | | | 4 | | 6 | | 9 | 19 | 2 | 38 | 76 | 58 |
| 75 | | | | | 5 | | 9 | | 6 | 20 | 1 | 20 | 20 | 22 |
| 72 | | | 2 | | 8 | | 7 | | | 17 | 0 | (182) | | |
| 69 | | | 5 | | 27 | | 1 | | | 33 | -1 | -33 | 33 | 41 |
| 66 | 1 | | 9 | | 9 | | 1 | | | 20 | -2 | -40 | 80 | 80 |
| 63 | | | 5 | | | | | | | 5 | -3 | -15 | 45 | 45 |
| 60 | | | 1 | | | | | | | 1 | -4 | -4 | 16 | 12 |
| 57 | | | | | | | | | | 0 | -5 | 0 | | |
| 54 | 1 | | | | | | | | | 1 | -6 | -6 | 36 | 30 |
| f | 2 | 0 | 22 | 0 | 53 | 0 | 31 | 0 | 43 | (151) | | (-98) | (762) | (610) |
| d | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | | | | | |
| fd | -10 | -0 | -66 | -0 | -53 | (-129) | 31 | 0 | 129 | (160) | | | | |
| fd | 50 | 0 | 198 | 0 | 53 | 0 | 31 | 0 | 387 | (719) | | | | |

$\frac{\Sigma XY}{N} = \frac{610}{151} = 4.04$

$C_X C_Y = .114$

$\sigma_X \sigma_Y = 4.73$

$C_X = \frac{-129 + 160}{151} = .205$ $\quad C_Y = \frac{182 - 98}{151} = .556$

$S^2_X = \frac{719}{151} = 4.76$ $\quad S^2_Y = \frac{762}{151} = 5.05$

$\sigma_X = 2.17$ $\quad \sigma_Y = 2.18$

$$r = \frac{\frac{\Sigma XY}{N} - C_X C_Y}{\sigma_X \sigma_Y} = \frac{4.04 - .114}{4.73} = \frac{3.926}{4.73} = .83$$

CHART

Coach - x

| Census y | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | f | d | fd | fd | xy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | | | | | | 0 | | | | |
| 87 | | | | | | 1 | | | 7 | 8 | 5 | 40 | 200 | 120 |
| 84 | | | | | 1 | | 3 | 1 | 8 | 13 | 4 | 52 | 208 | 112 |
| 81 | | | | | 1 | | 4 | 2 | 2 | 9 | 3 | 27 | 81 | 39 |
| 78 | | | | | 2 | | 3 | 4 | 6 | 15 | 2 | 30 | 60 | 54 |
| 75 | | | 1 | 1 | 11 | 3 | 9 | 4 | 3 | 32 | 1 | 32 | 32 | 10 |
| 72 | | | 1 | 3 | 6 | 5 | 9 | 4 | | 28 | 0 | (181) | | |
| 69 | | | | 1 | 11 | 4 | 6 | | | 22 | -1 | -22 | 22 | 7 |
| 66 | | | | 2 | 6 | 1 | | 1 | | 10 | -2 | -20 | 40 | 16 |
| 63 | | | | 4 | 6 | 1 | | | | 11 | -3 | -33 | 99 | 42 |
| 60 | | | 1 | | | | | | | 1 | -4 | -4 | 16 | 12 |
| 57 | | | 1 | | | | | | | 1 | -5 | -5 | 25 | 15 |
| 54 | | | | 1 | | | | | | 1 | -6 | -6 | 36 | 12 |
| | | | | | | | | | | (151) | | (-90) | (819) | (439) |
| f | 0 | 0 | 4 | 12 | 44 | 15 | 34 | 16 | 26 | | | | | |
| d | | | -3 | -2 | -1 | 0 | 1 | 2 | 3 | | | | | |
| fd | | | -12 | -24 | -44 | (-80) | 34 | 32 | 78 | (144) | | | | |
| fd | | | 36 | 48 | 44 | | 34 | 64 | 234 | (460) | | | | |

$\frac{\Sigma XY}{N} = \frac{439}{151} = 2.907$

$C_x C_y = +.255$

$\sigma_x \sigma_y = 3.809$

$C_x = \frac{-80+144}{151} = .4238$

$C_y = \frac{-90+181}{151} = .6026$

$S^2_x = \frac{460}{151} = 3.046$

$S^2_y = \frac{819}{151} = 5.423$

$\sigma_x = 1.694$

$\sigma_y = 2.249$

$$r = \frac{\frac{\Sigma XY}{N} - C_x C_y}{\sigma_x \sigma_y} = \frac{2.907 - .255}{3.809} = \frac{2.652}{3.809} = +.69$$